Development of a Global 3D Upper Mantle Velocity Model for Regional Pn and Sn Calibration in Western Eurasia, the Middle East, Northern Africa, and Europe - The Group 2 Location Calibration Consortium Phase 1 Model Delivery

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The Group-2 Consortium is carrying out seismic location calibrations for IMS stations in the Mediterranean, North Africa, Middle East, and Western Eurasia using 3D models. Source Specific Station Corrections (SSSCs) for IMS seismic stations are developed to improve location accuracy and reduce error ellipses. We define the calibrated region as a rectangle covered by the 20 degree circles around 32 designated Group-2 stations (http://g2calibration.cmr.gov/). Our goal is to develop Pn and Sn SSSCs for a source depth of 10 km. We define the regional SSSCs on rectangular grids where both a travel-time correction and a modeling error are given at each grid point. The 10 km source depth is a compromise for all regions of crustal seismicity. We compare the model-based corrections to empirical path corrections, and we locate GT events to demonstrate improvement in event locations when using the corrections.

CUB1.0 shear-velocity model is created from a large data set of surface wave fundamental mode phase and group velocity measurements. Phase velocities in period range between 40 and 150 s are obtained from Harvard University and Utrecht University (Ekström et al.,1997; Trampert and Woodhouse, 1995, respectively). The group velocity measurements at periods between 16 and 200s are performed at the University of Colorado at Boulder. Data coverage is better for Rayleigh waves, at intermediate periods. The coverage is best in Eurasia and worst in Africa. The starting model of crust and upper mantle was built upon several global models and regional information for Eurasia including the UCSD sediment model and CRUST5.1 crustal model (Mooney et al., 1998) and an upper mantle shear velocity model based on the S20A model (Ekström and Dziewonski, 1998) modified with radial anisotropy from PREM. This model has the radial-average velocity structure of AK135 model to remove the 220 km discontinuity in PREM. We construct the group and phase velocity maps using the ray-based tomography technique of Barmin et al. (2001). Monte-Carlo inversion of the dispersion curves produces at every geographical location an ensemble of acceptable shear velocity models of the crust and uppermost mantle from which average characteristics and uncertainties are extracted. Empirical logarithmic scaling relations allow us to infer compressional velocities from shear velocities. The upper mantle velocities of the CUB1.0 Model are constrained by Pn maps. Uncertainty estimates allow the identification of the robust features of the model, which, typically, persist to depths of greater than 250 km. We compute SSSCs using ray tracing for IMS stations, IMS surrogates, and other non-IMS stations for validation and testing. We use a 2D ray tracer for numerical calculation of travel times for refracted and reflected P or S waves in 3D laterally inhomogeneous media along 2D cross sections of a spherical earth.

We compared the model based path corrections and empirical path corrections for cross-validation and model error evaluation. About 4,000 P-phase empirical cluster-station path corrections at regional distances were estimated with JHD (Joint Hypocenter Determination) for 47 clusters in Europe, Middle East, and North Africa. Model-based path corrections (SSSCs) show encouraging agreement with empirical JHD corrections with significant correlation for more than 80% of the clusters. Correlation values were also generally higher for paths longer than 5 degrees, indicating the length scale of the structures resolved by the CUB1.0 model. The median of the corrections is slightly positive (0.6 sec), indicating slower travel times than that of IASPEI91 on average. Fast paths are concentrated in the northern shield/platform regions and slow paths in the southern tectonic regions. The overall spread in the path corrections are characterized by a standard deviation of 1.53 sec and the JHD corrections span a larger range than the corresponding CUB1.0 values. Standard deviations of the differences in CUB1.0 SSSC - JHD path corrections range from 0.56 to 1.92 with a median of 1.15. The reduction of this measure by CUB1.0 from about 1.53 to 1.15 suggests improvement in calculated travel times with the CUB1.0 model relative to empirically observed times. This corresponds to an overall variance reduction of 44%.

We estimate the modeling errors, the uncertainty in the predicted travel times, to ensure 90% ellipse coverage. These error estimates are important because they are used, together with measurement errors, to weigh phase picks in event locations and to construct error ellipses. We ray traced through the CUB1.0 model to predict the travel times of over 1,000,000 Pn rays. We computed the model misfits by comparing the predicted travel times with the observations from the EHB bulletin. Model error for Pn is calculated from the standard deviations of the Pn misfits as a function of distance. Sn error is obtained by scaling Pn errors by a factor of two. The average misfit grows nearly linearly until about 15° and then decreases. This 10° - 15° feature results predominantly from errors in predicting the distance where Pn transitions to a diving P. Predictions of the onset of the Pn to diving P transition are very sensitive to the upper mantle vertical gradient. Therefore, small changes in the model produce moderate changes in travel time predictions in the 10° - 15° range.

We carry out relocation tests using a large GT dataset to validate the model predicted corrections and the modeling error estimates.